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**Surface Morphologies and Electrical Properties
of Molecular Beam Epitaxial InSb and
InAs_xSb_{1-x} Grown on GaAs and InP Substrates**

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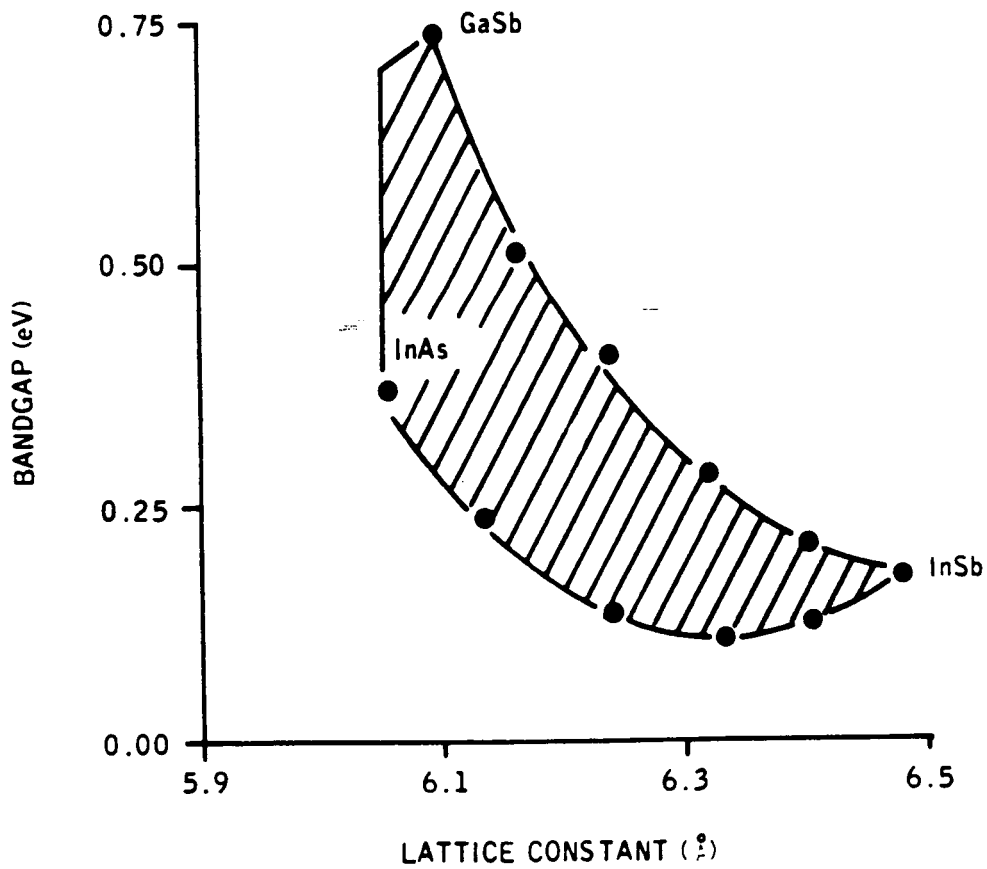
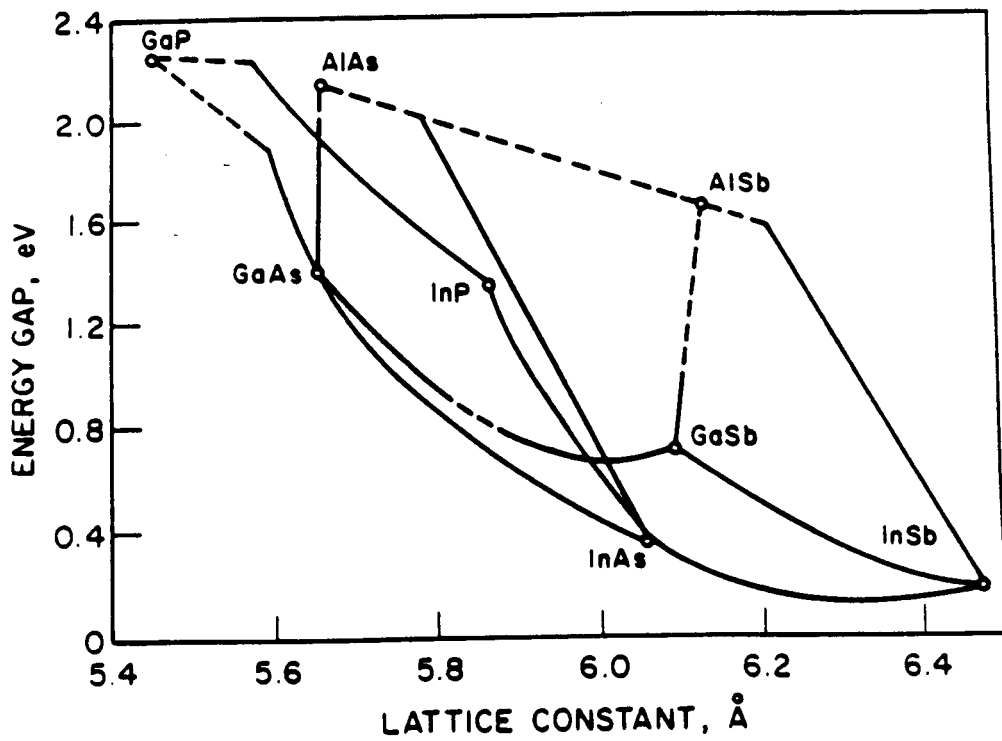
(NASA-CR-185439) SURFACE MORPHOLOGIES AND
ELECTRICAL PROPERTIES OF MOLECULAR BEAM
EPITAXIAL InSb AND InAs(x)Sb(1-x) GROWN ON
GaAs AND InP SUBSTRATES (Michigan Univ.)
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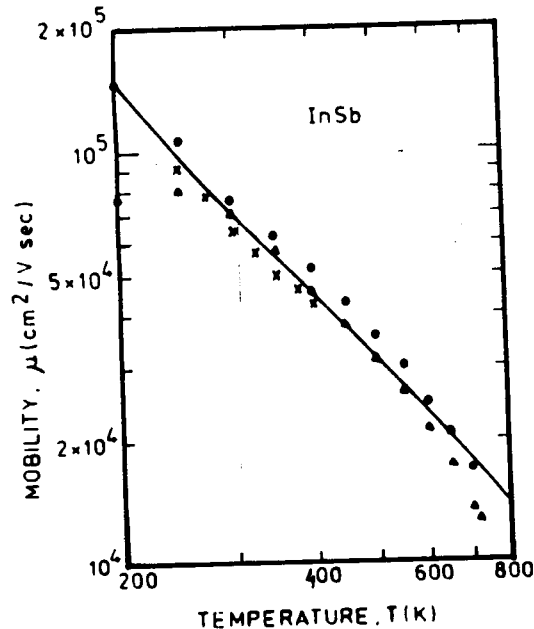
CSCL 20L G3/76 0218569

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REVIEW

- Bandgap of InSb (300 K) = 0.17 eV
(77 K) = 0.22 eV
- Bandgap of InAs_{0.4}Sb_{0.6} (300 K) = 100 meV
(77 K) = 140 meV
- InAsSb/InSb SLS (Sandia) $\sim 12 \mu\text{m}$
Bandgap of SLS varies slowly with composition.
Hence lateral composition variations will not
result in large changes in wavelength response.
- Bulk InSb Properties



- Epitaxy

LPE of InAsSb on InSb (n- and p-type)
– Abrokwa and Gershenzon

MBE of InSb and InAsSb on GaAs and InAs.

- | | |
|----------------|--------------------|
| –Noreika et al | –Chyi et al |
| –Yen et al | –Williams et al |
| –Bethea et al | –Davis and Thomson |

Low mobilities at low temperatures.

OUTLINE

- MBE growth of $\text{InAs}_x\text{Sb}_{1-x}$ ($0 \leq x \leq 0.55$)
using Sb_4 and As_4 on GaAs and InP
- Morphology
- X-ray diffraction
- Electrical Characteristics

Molecular Beam Epitaxial Growth of $\text{InAs}_x\text{Sb}_{1-x}$

Substrates: GaAs (100), (311)A, (311)B
InP (100)

Preparation by solvent degreasing and
etching oxide desorption in growth chamber
at 620°C (GaAs) and $\sim 520^\circ\text{C}$ (InP)

Growth Parameters:

$$T_g = 350 - 500^\circ\text{C}$$

$$R_g = 0.8 - 1.0 \mu\text{m/hr.}$$

$$P_{\text{As}_4} = 1.5 \times 10^{-5} \text{ Torr}$$

$$J_{\text{Sb}_4}/J_{\text{In}} (\text{InSb}) = 0.3 - 4.0$$

Growth Structures:

2.5-6.0 μm	<u>InAsSb</u>	1.0-14.0 μm	<u>InAsSb</u>
0.5 μm	<u>GaAs buffer</u>		<u></u>
	<u>GaAs subs.</u>		<u>InP substrate</u>

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Electron Diffraction Pattern

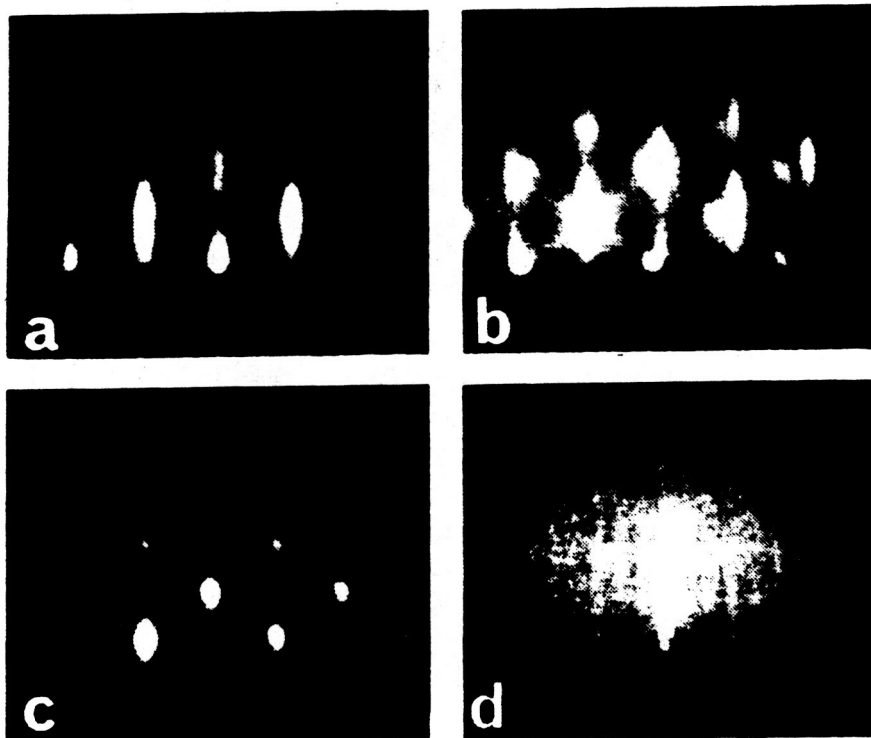


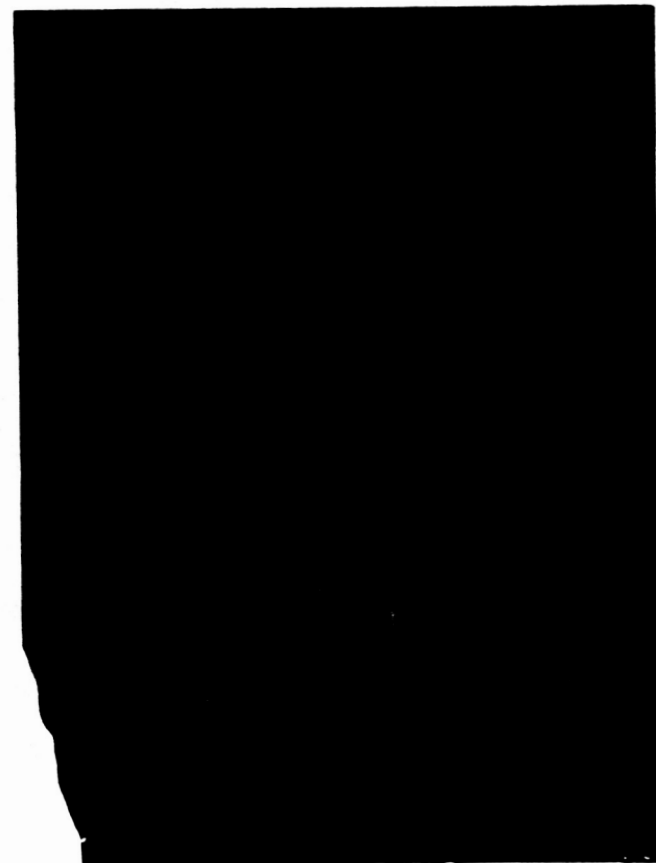
FIG. 1. 15 keV RHEED patterns along $[110]$ azimuth of (a) GaAs (100) substrate immediately prior to growth, (b) 0.3-nm-thick InSb layer grown at a substrate temperature of 375 °C, (c) 10-nm-thick InSb layer, (d) 30-nm-thick InSb layer.

Ref. Williams et al, Appl. Phys. Lett. 53 (13), 1189 (1988)

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$T_g = 380^\circ\text{C}$ $R = 1.0 \mu\text{m/hr}$



a

$J_{Sb4}/J_{In} = 2.02$

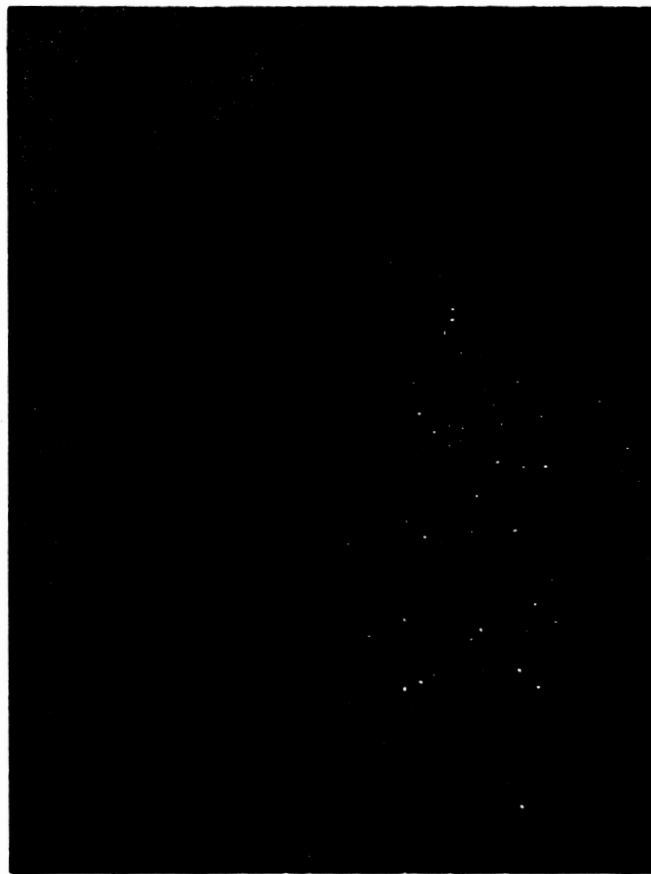
b

$J_{Sb4}/J_{In} = 3.64$



c

$J_{Sb4}/J_{In} = 1.45$



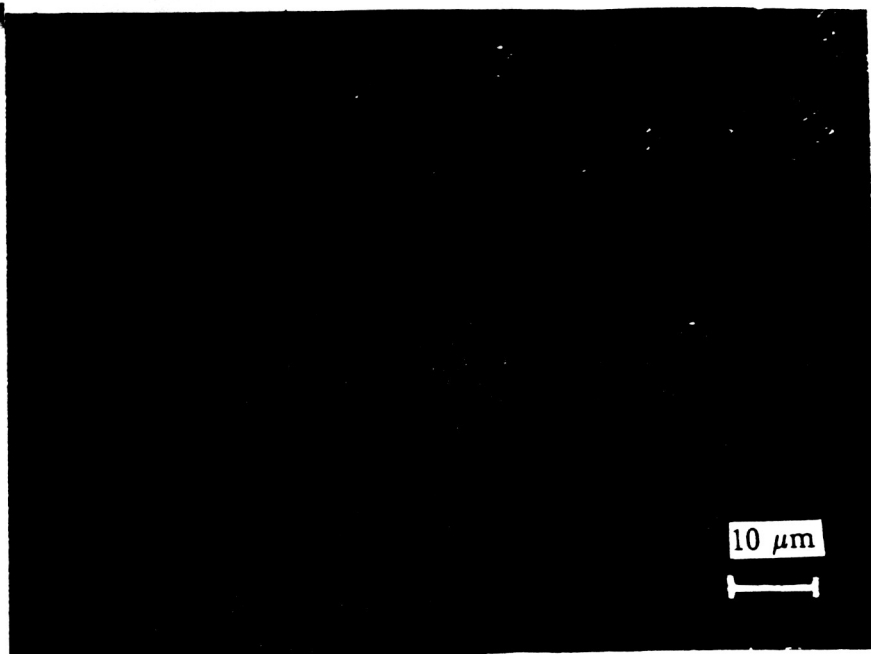
d

$J_{Sb4}/J_{In} = 0.75$

Morphology of $\text{InAs}_x\text{Sb}_{1-x}$

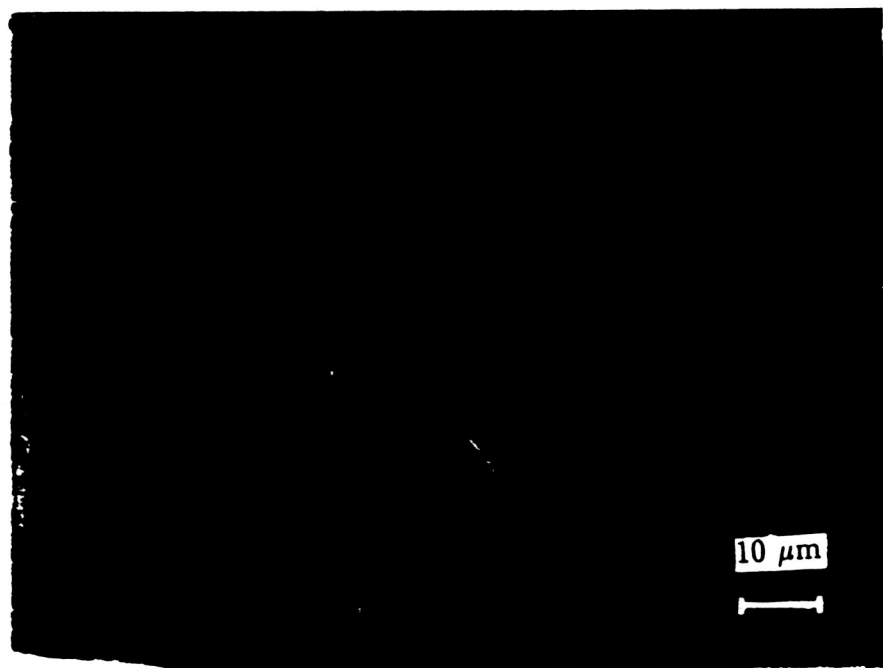
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$T_g=400^\circ\text{C}$
 $J_{\text{Sb4}}/J_{\text{In}}=1.82$
 $t=6.4\text{ }\mu\text{m}$



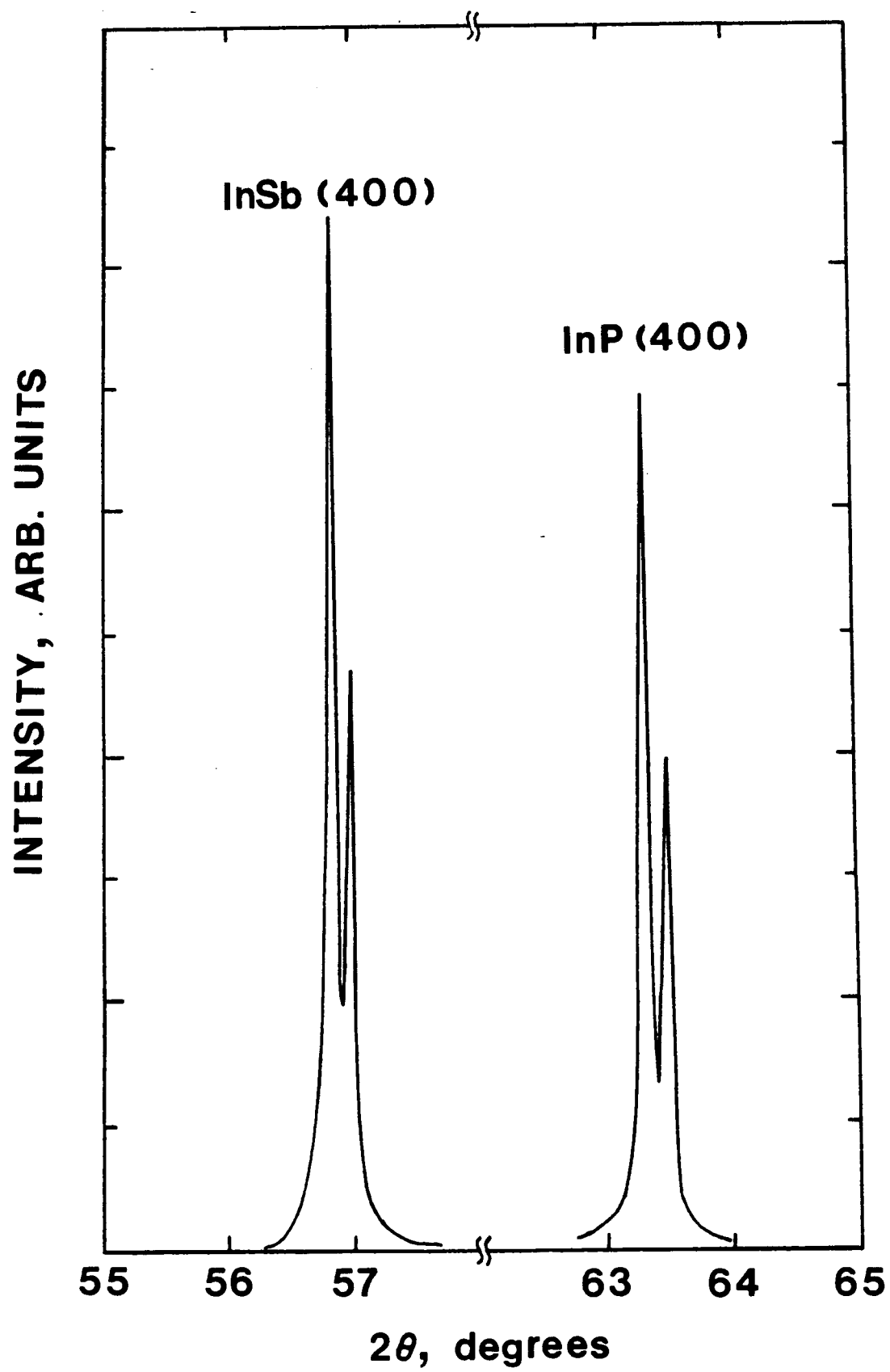
$x=0.14$

$T_g=370^\circ\text{C}$
 $J_{\text{Sb4}}/J_{\text{In}}=1.07$
 $t=6.4\text{ }\mu\text{m}$

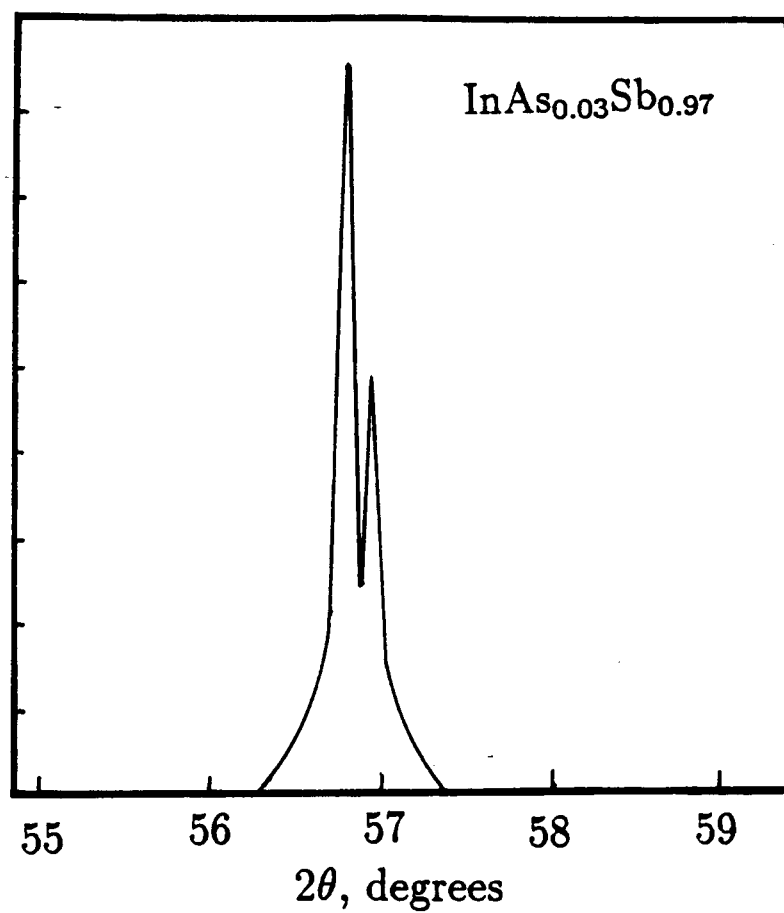


$x=0.03$

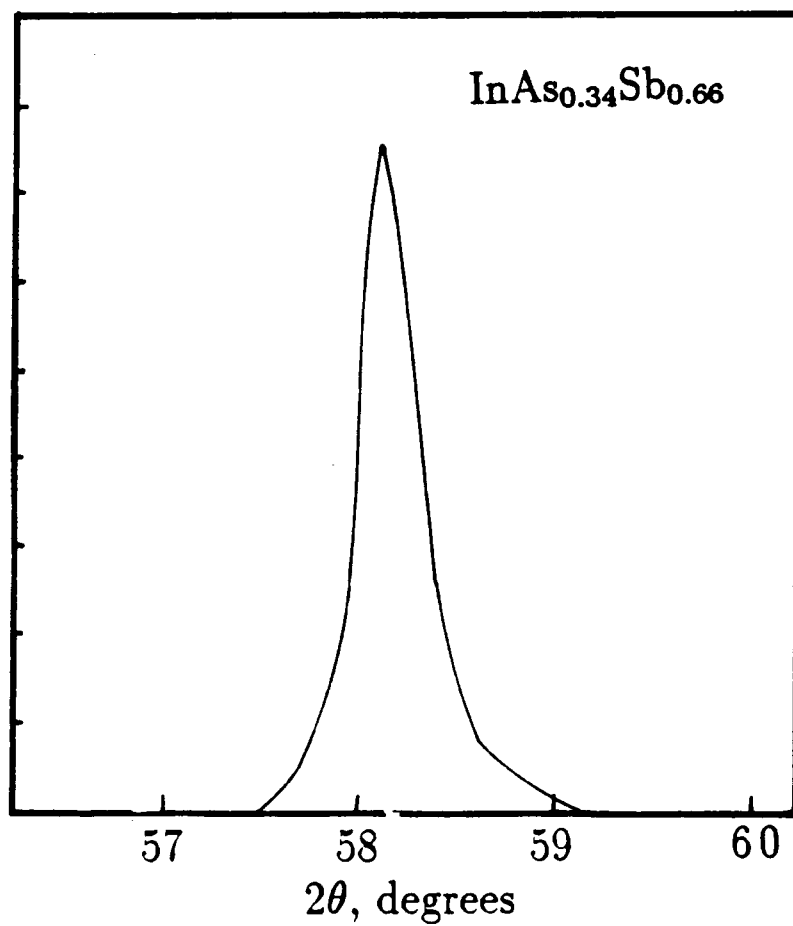
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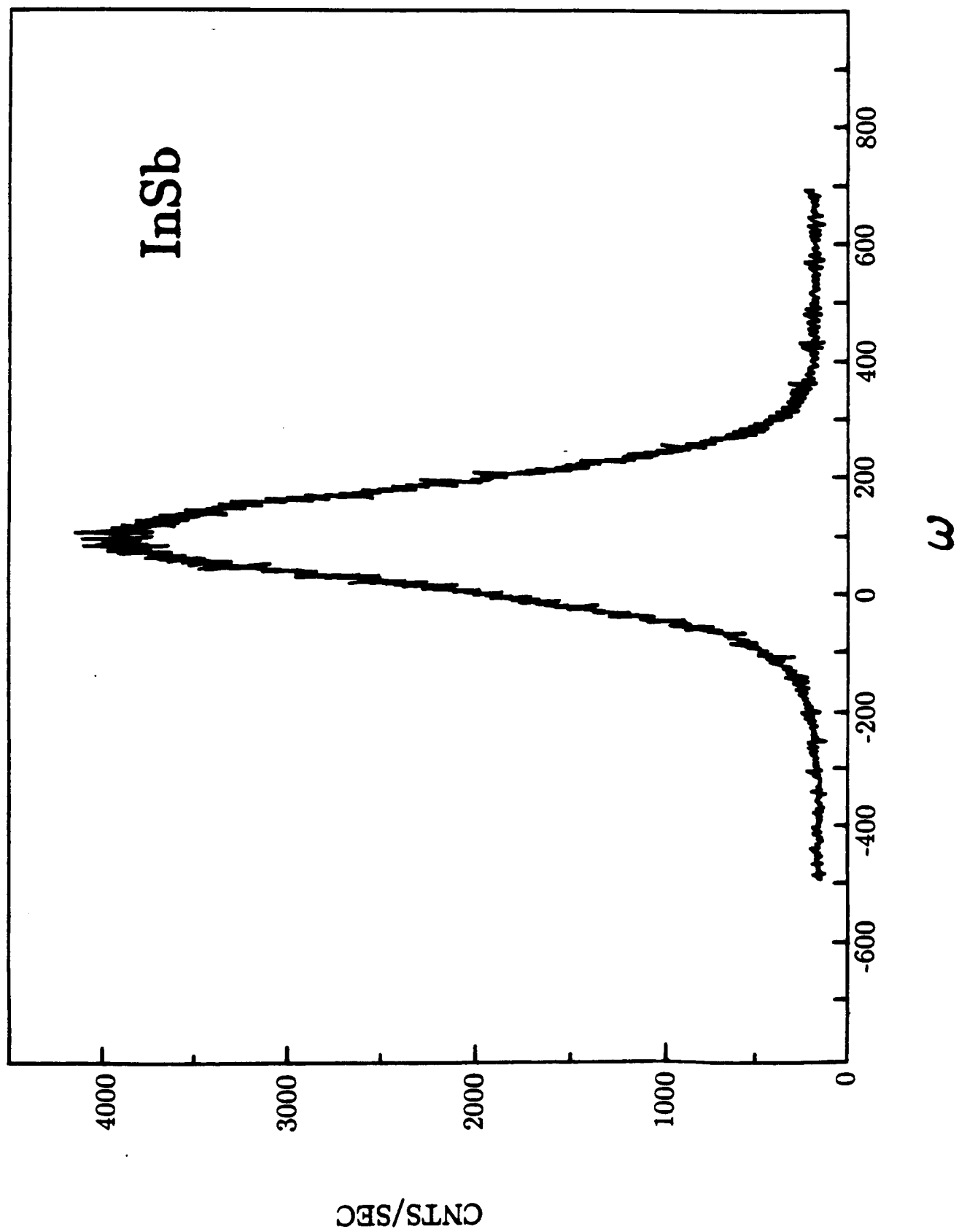


Intensity, Arb. Units

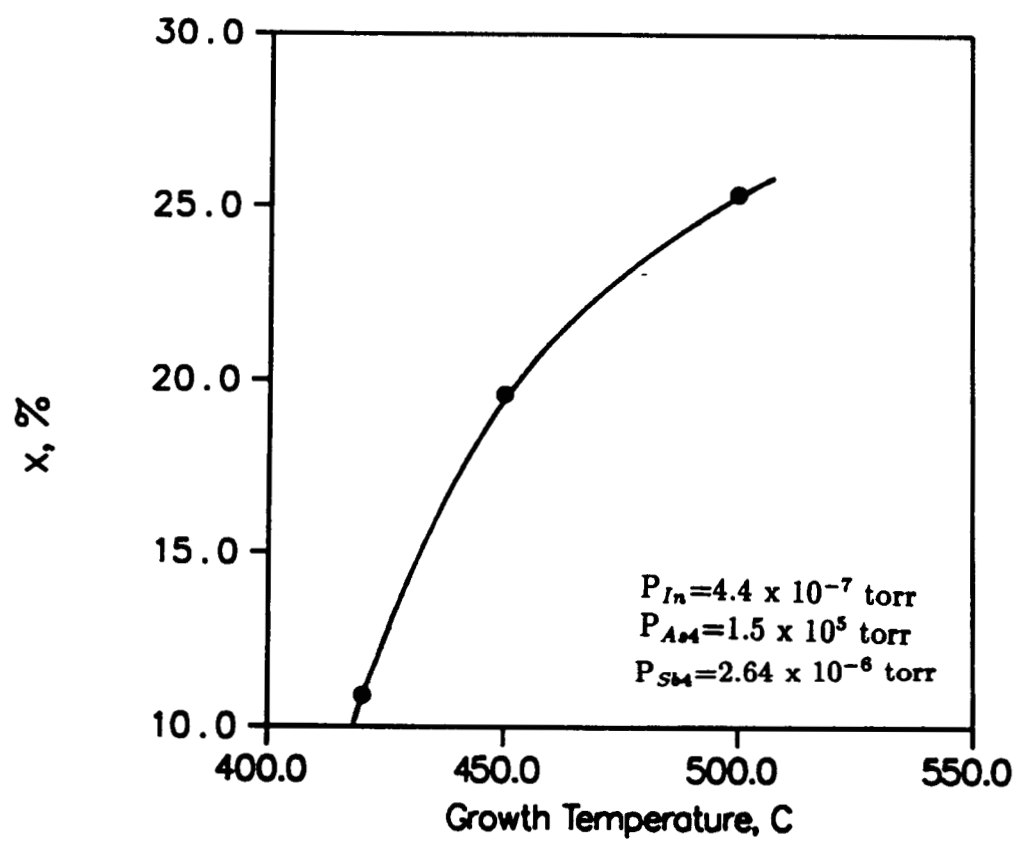


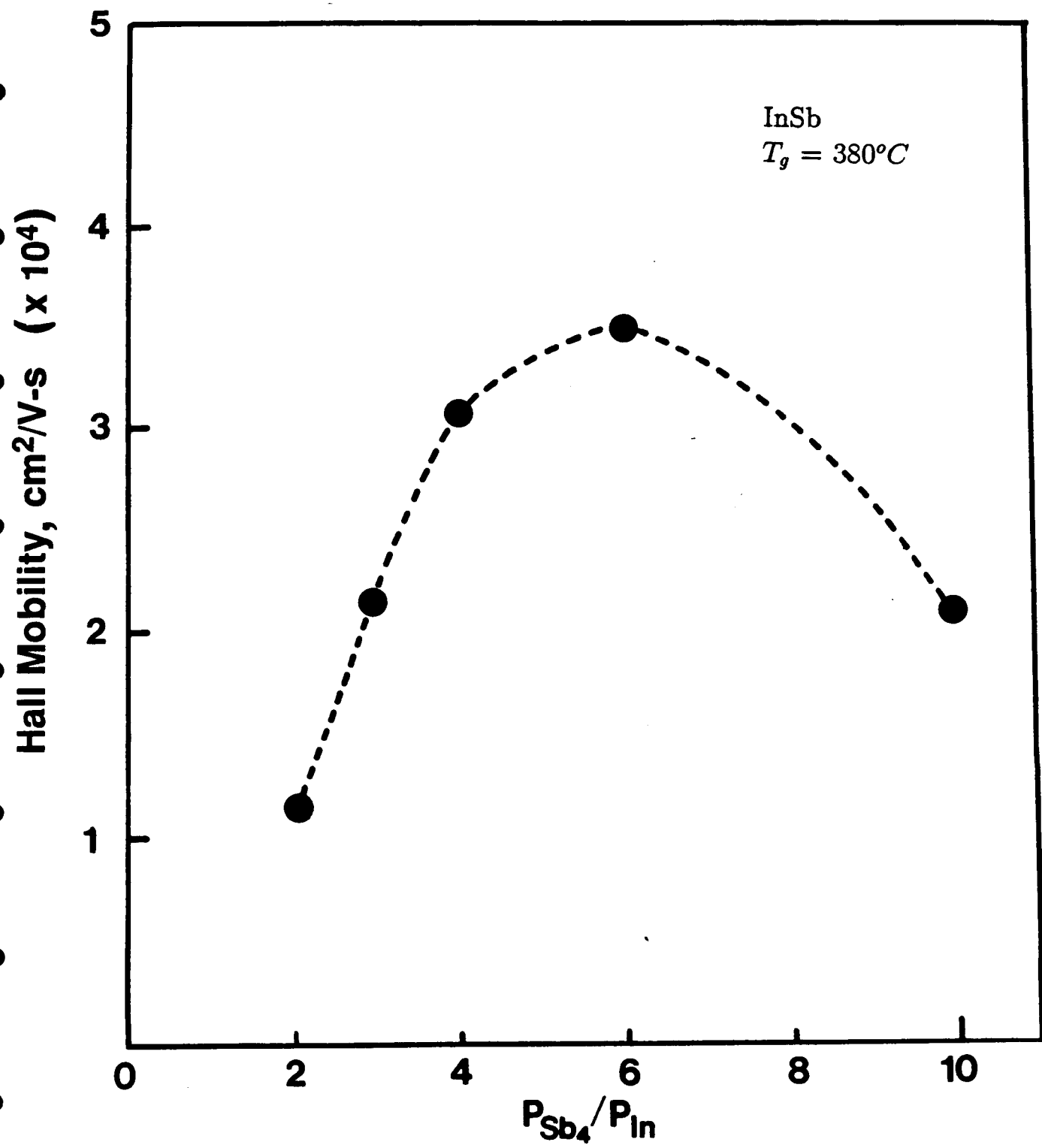
Intensity, Arb. Units



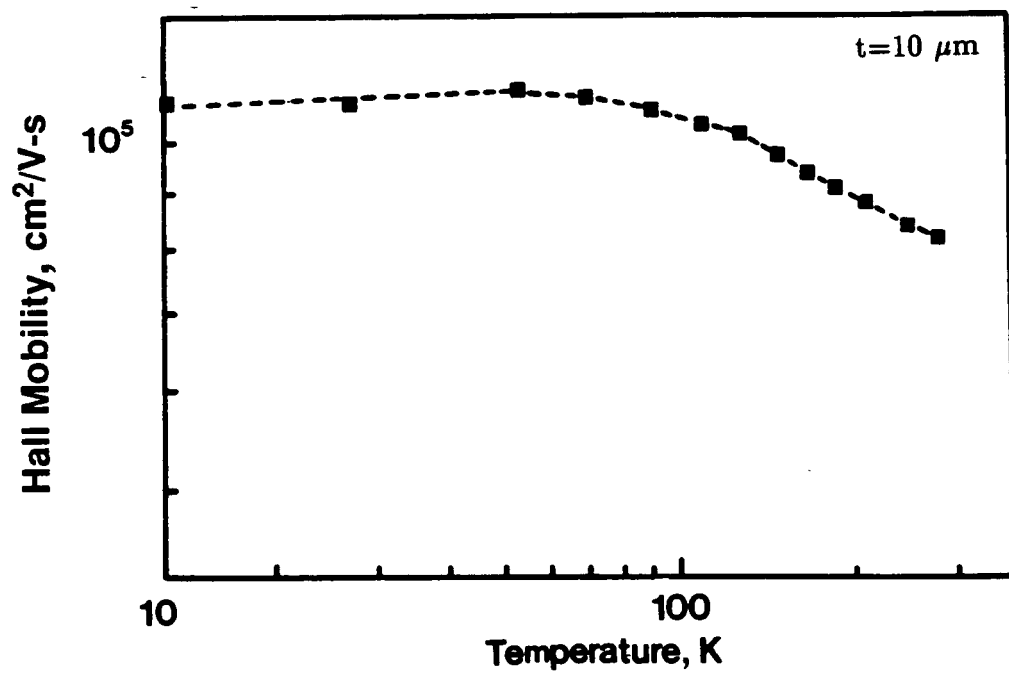


Growth Temperature vs Composition

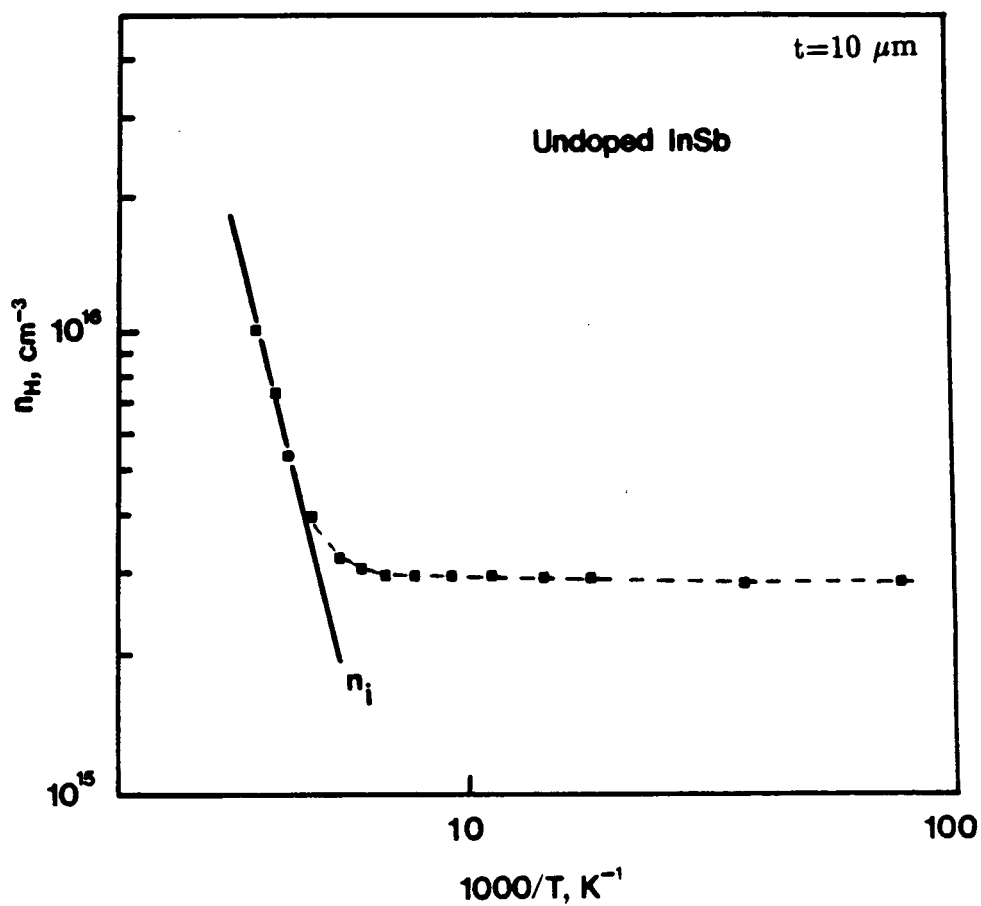




Electrical Characteristics of InSb on (100) InP

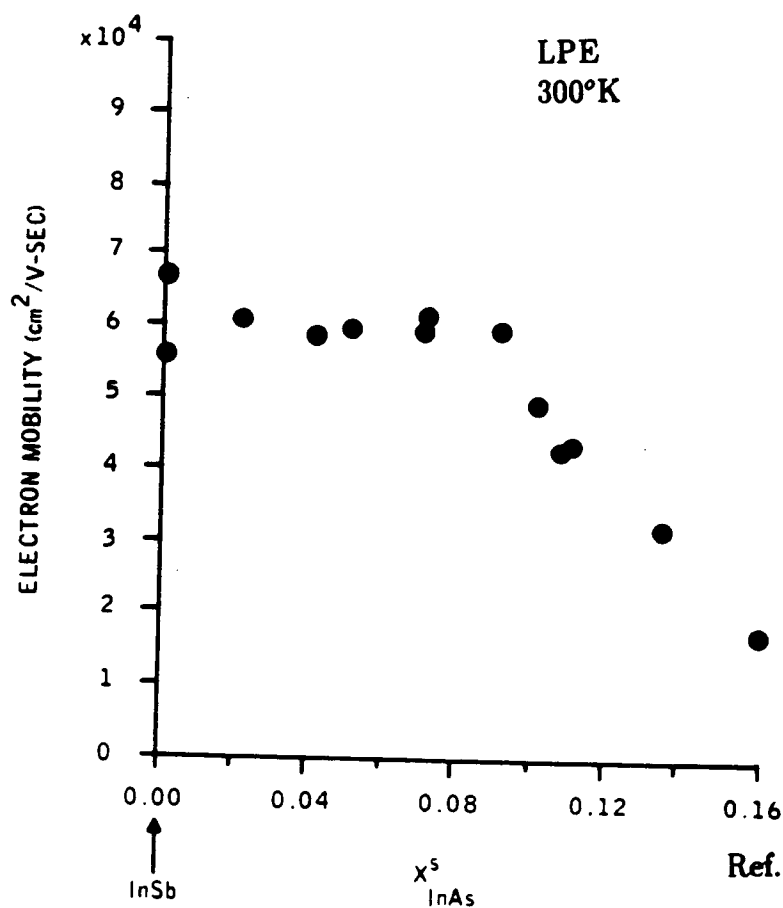
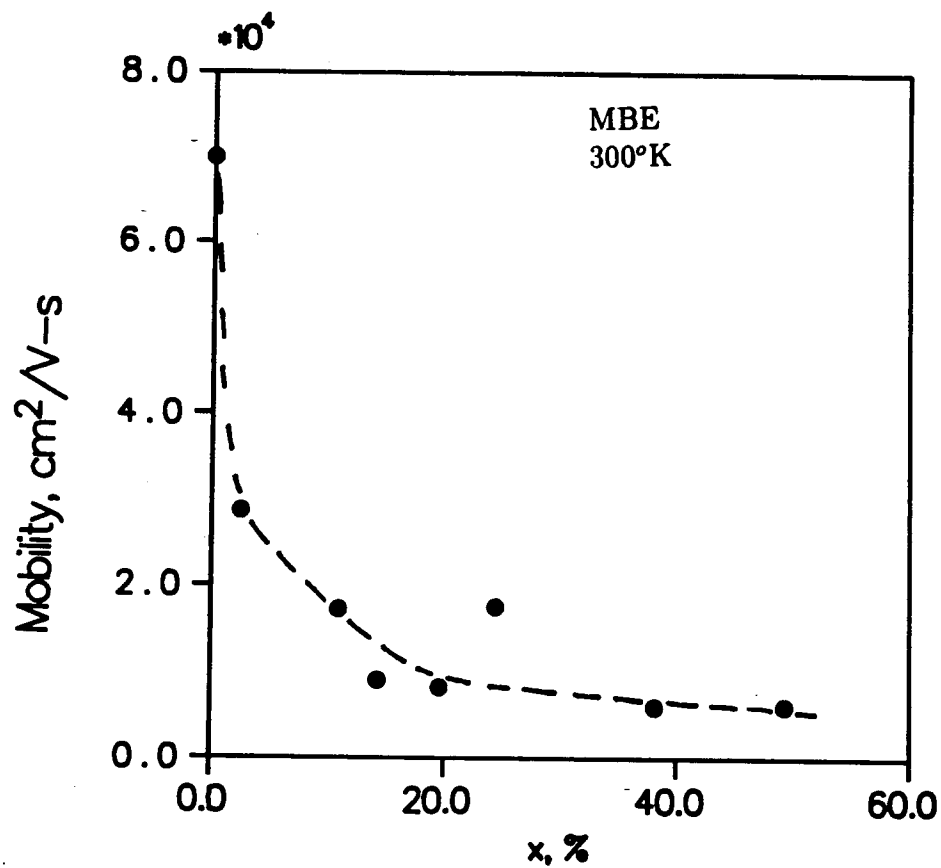


[a]



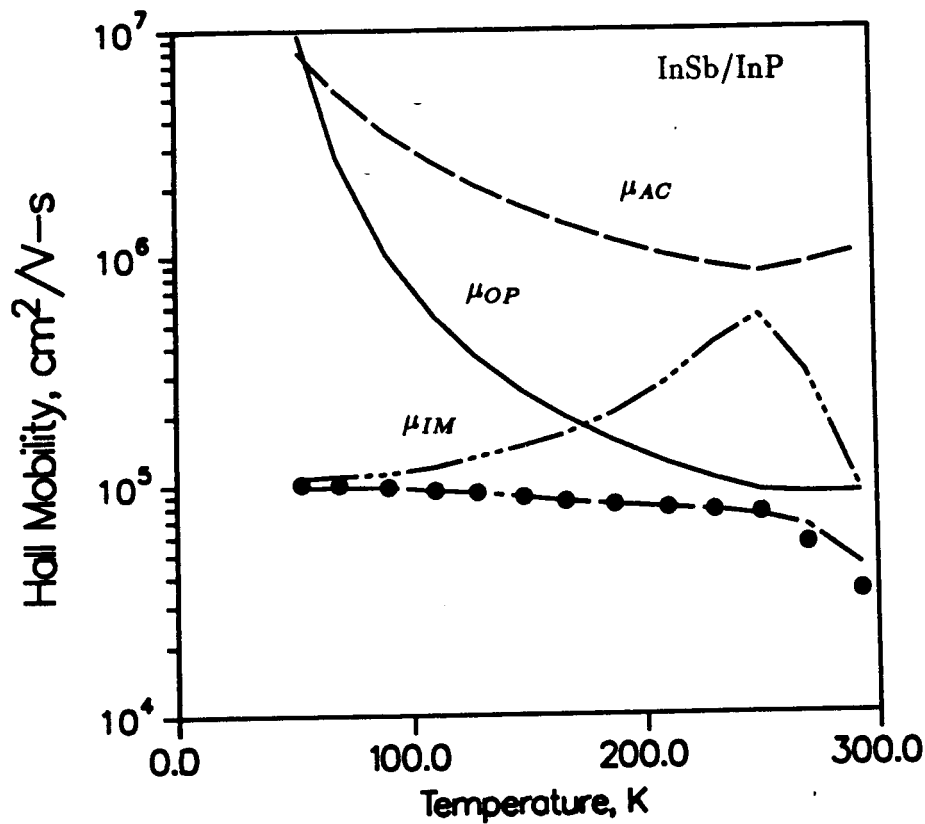
[b]

Mobility vs. Composition in $\text{InAs}_x\text{Sb}_{1-x}$

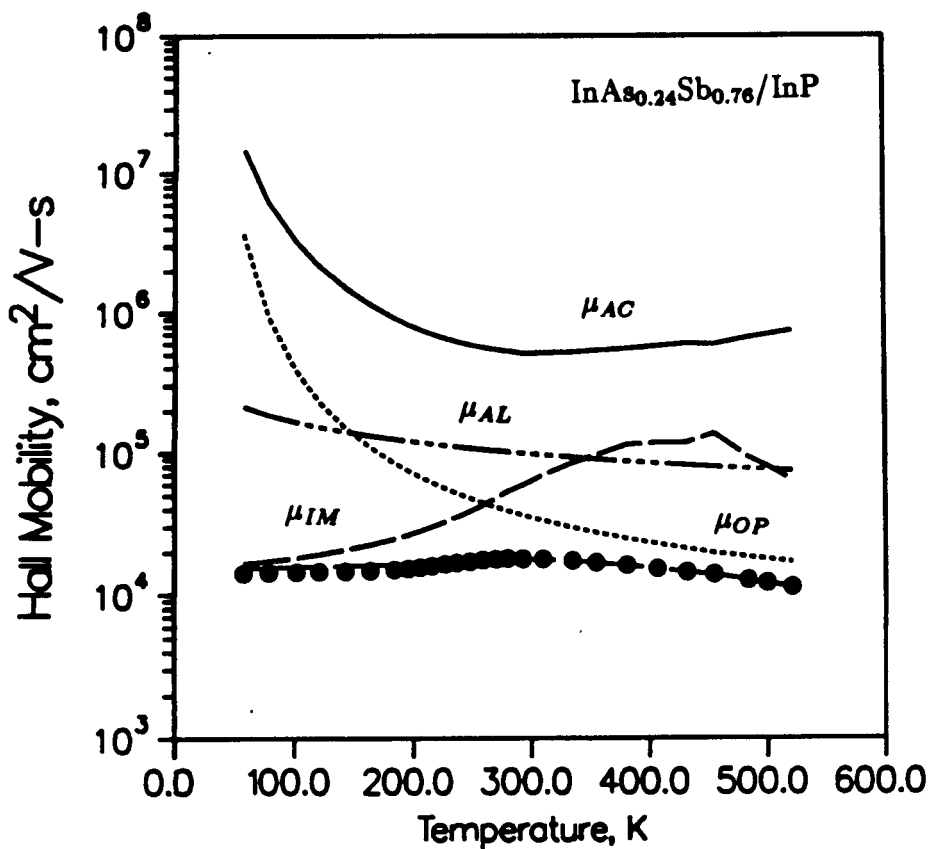


Ref. Abrokwhah and Gershenzon
J. Electron Mater. 10, 379(1981)

Analysis of Carrier Mobility in $\text{InAs}_x\text{Sb}_{1-x}$

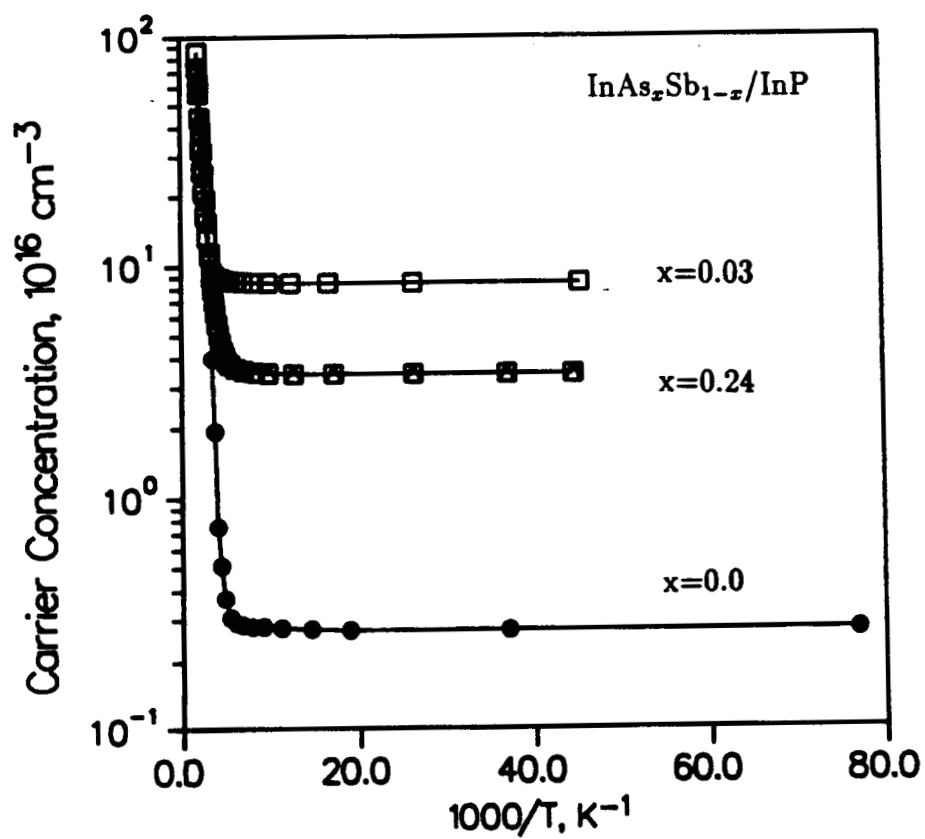


Parameters		unit
E_g	0.20	eV
m_e^*/m_o	0.0145	-
ϵ_∞	15.60	ϵ_o
ϵ_s	17.64	ϵ_o
θ_o	278	$^\circ\text{K}$
ρ	5.8×10^3	kg/m^3

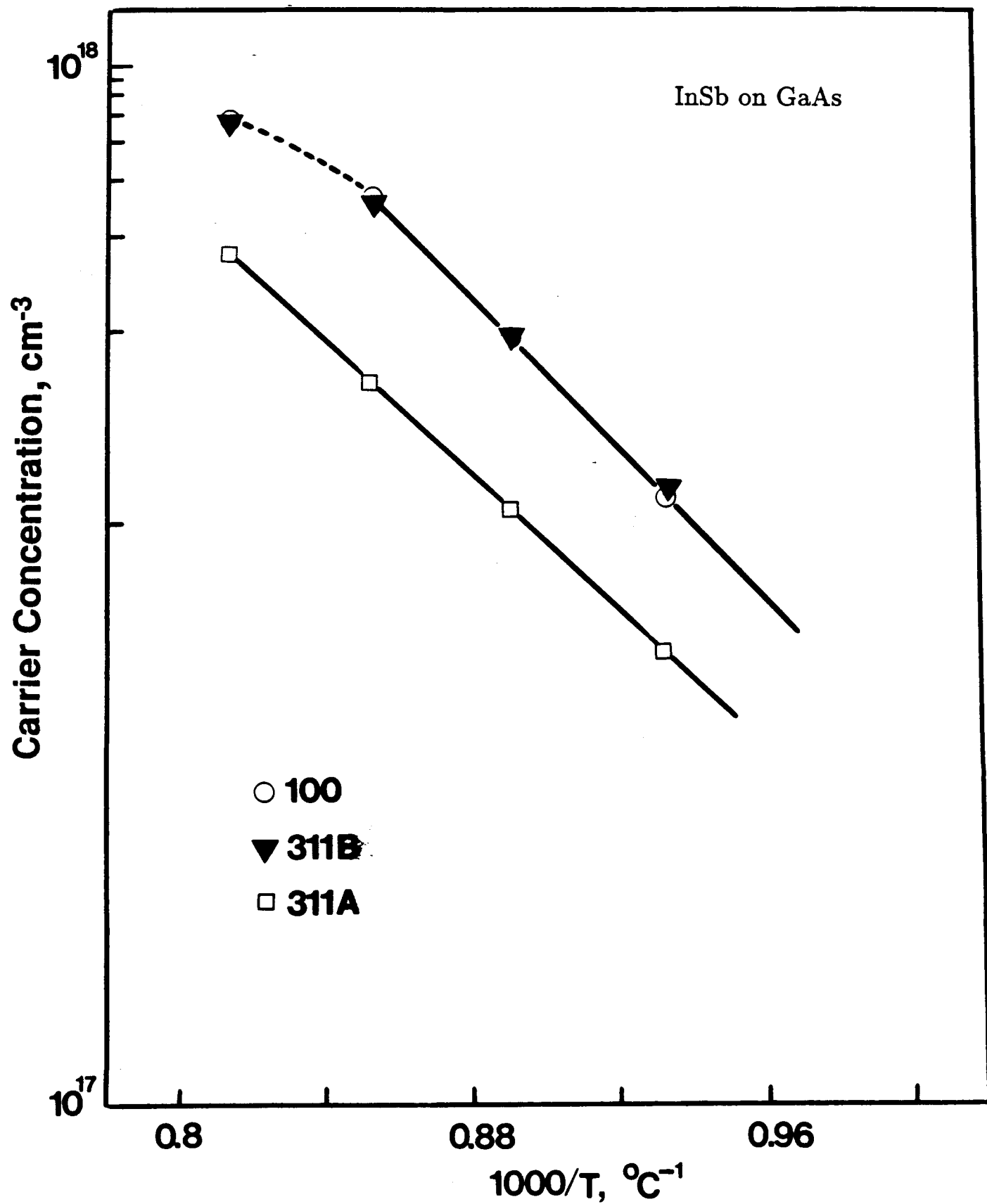


Parameters		unit
E_g	0.24	eV
m_e^*/m_o	0.016	-
ϵ_∞	14.72	ϵ_o
ϵ_s	16.81	ϵ_o
θ_o	292	$^\circ\text{K}$
ρ	5.75×10^3	kg/m^3

Carrier Concentration vs Temperature



InSb on GaAs



SUMMARY

1. Good quality $\text{InAs}_x\text{Sb}_{1-x}$ has been grown directly on InP substrates by molecular beam epitaxy.
2. The crystals are all n-type at 300K and lower temperatures.
3. The surface morphology and electrical characteristics are strongly dependent of Sb_4/In flux ratio and substrate temperature.
4. The highest mobilities in InSb on InP are 70,000 at 300K and 110,000 $\text{cm}^2/\text{V.s}$ ($n = 3 \times 10^{15} \text{ cm}^{-3}$) at 77K.
5. The mobilities in the alloys also increase monotonically with lowering of temperature.